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ABSTRACT

This study tested the ability of two semantic-memory models, feature-comparison and network, to explain differences in information processing times. The feature-comparison model assumes that an item's meaning is held in semantic memory as a set of characteristic and defining features, while the network model assumes that semantic memory is comprised of hierarchically arranged, superordinate and subordinate nodes. Each model makes different predictions about reaction times for information processing (retrieval and/or comparison). After fourteen subjects read a story that enumerated the characteristics and defining features of a hierarchy of fictitious animals and familiarized themselves with that hierarchy, they responded to 107 propositional statements about the animals' features and interrelationships. Subjects' reaction times in responding to the propositional statements were compared with each model's predicted reaction times. Results show that neither model predicted reaction times accurately. A discussion of the results indicates that semantic memory is influenced by the form that a message takes, by the external cues that a communicator presents, and by the ways that people consciously order the messages they receive. (RL)

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A Critical Comparison of the Network and Feature Comparison Models of Semantic Memory

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A CRITICAL COMPARISON OF THE NETWORK AND FEATURE COMPARISON MODELS OF SEMANTIC MEMORY

Introduction

In the research literature, long-term memory is typically divided into two categories--episodic and semantic. Episodic memory deals with an individual's unique, picture-like record of personal life experiences. Semantic memory retains words, their meanings and referents, the relationships that hold among words and the rules for manipulating words (Tulving & Donaldson, 1972, p. 382-403). Thus, semantic memory is an integral part of all language use. It is the storehouse to which incoming language production is compared for meaning.

The structure of semantic memory, or how verbal concepts are held in memory, must be understood before the questions of retrieval and access (comparison) can even be broached. Two models of the structure of semantic memory, the feature-comparison model and the network model, claim the allegiance of most of the recent researchers in this area.

Work testing the utility of these two models has never adequately controlled for past associations between the stimulus and category items presented in experiments. Research testing the network model has relied on intuitive judgment as the "control" for subject's representations of concepts in memory. Those testing the feature-comparison model have used multiple scaling techniques for this purpose.

It is our position that neither model can be carefully tested without more rigorous control of subject's past associations between a stimulus and its target category. To this end, we have constructed a fictitious hierarchical system of interrelated concepts that are not grounded in the pasts of any of our subjects. The system of concepts we designed was constructed to meet the theory testing demands of both the feature-comparison and the network model.

Stimulus-category pairings were set-up to test the predictive utility of both models.

Literature Review--Feature Comparison Model

Feature-comparison proponents (Bock, 1976; Rips, Shoben and Smith, 1975; Rips, Smith and Shoben, 1975; Shoben, 1976; and Smith, Shoben and Rips, 1974) assume that an item's meaning is held in memory as a set of semantic features. These features fit into two classes: characteristic features and defining features. Characteristic features are typical of an item but not essential for its description (e.g. given the question: "Is a robin a bird?", a characteristic feature of both robins and birds is that they can fly. Most, but not all, birds can fly.) Defining features are necessary for the inclusion of an item in a category (e.g. a robin has feathers and all birds have feathers).

As outlined by Smith, et. al. (1974), the feature-comparison model incorporates two, sequential stages of comparison. In stage I, both characteristic and defining features of an item are compared to the characterisitc and defining features of the target category. If both the characteristic and defining features of both the item and category are judged "sufficiently" (this word is never explicitly defined) similar or dissimilar, a decision of membership or nonmembership is immediately made. If there is some, but not an overwhelming, similarity or dissimilarity between the features of an item and the features of its category, then the second-stage of semantic memory must decide for inclusion or noninclusion. In this second stage all defining features, but no characteristic features, are compared. After stage II a definite decision is made.

Although the majority of research testing this model has been supportive (Rips, et. al., 1975), a recent study by Holyoak and Glass (1975) produced findings contrary to those predicted by the feature-comparison model. As previously stated, the feature-comparison model predicts that two items very similar in terms of their characteristic features but not in terms of their

defining features, would activate the second stage of processing and that a comparison of two items that were substantially different would not activate stage II processing. Glass and Holyoak (1975) found the opposite to be true. These contradictions could be merely a function of the model's difficulty in controlling for the number of past associations held by the subjects of the experiment.

LITERATURE REVIEW - NETWORK MODEL OF SEMANTIC MEMORY

Network model adherents (Collins and Loftus, 1975; and Collins and Quillian, 1969; 1970) postulate that semantic memory is comprised of a network of hierarchically arranged superordinate and subordinate semantic nodes. Properties of items and their ascendingly more general classes are assumed to be stored at only one node in the hieracrchy.

When a stimulus item is presented to a subject, a specific semantic node is activated. The activation then spreads to related nodes with an intensity that diminishes as it moves away from the original node in the semantic hierarchy. The subject's reaction time (RT) for stimulus/category relations that are true (e.g. Is a canary an animal?) is directly related to the number of semantic nodes a stimulus must pass through prior to the final comparison node (canary-bird-animal). Given a false comparison instance (Does a canary have gills?) a search along a criterial number of paths is initiated until all have been exhausted without a true indicant. Only after the subject has rejected "all" (here Collins and Quillian, 1969, are vague) paths does he respond false. Thus the RT for false statements is "long but highly variable" (Collins and Quillian, 1969). As with the semantic feature model, the unknown number of past associations (nodes to cross and paths to exhaust) presents a major problem to this research.

Collins and Quillian (1975) attempted to finally resolve the feature comparison model vs. network model controversy. That these attempts were not successful is evidenced by the ongoing debate and further research in this area

(Bock, 1976; Shoben, 1976).

Shoben (1976) commented that any viable theory of semantic memory must account for individual meanings (past associations) of words. The purpose of this study is to provide an empirical framework by which past associations can be controlled. Thereby, the assumptions of each model can be given a fair test.

To control for a subject's past associations of word meanings, we have created a fictitious category system for which our subjects can have no past associations. By so doing, the number and meaning of defining and characteristic features of an item (feature comparison model) and the number of accessible semantic nodes (network model) can both be held constant.

This experiment was designed to determine which of the two semantic memory models would best predict RT. True and false propositional statements were written such that each theory made different predictions for the same propositional statement.

METHODS

Subjects: Fourteen subjects were used in this experiment, seven male and seven female. They ranged in age from 19 years to 26 years. All subjects participated to fulfill a class requirement. Although the number of subjects used is small, it exceeds that of the eight person subject pool used by Collins and Quillian (1969).

Materials: A hierarchical category system of mythical animals from another planet was constructed and embedded in a story concerning the survival of the crew of a downed space craft. The characteristics and defining features of the mythical animals were enumerated in the story and assigned to different hierarchical levels. Essentially, the subjects in their roles of downed spacemen were told they needed to know the different animals and their properties in order to eat--and to avoid being eaten. The animal names were nonsense words of the type consonant-vowel-consonant and consonant-vowel-consonant-consonant.

The features were descriptive, easily understood, English words. Table I provides this information in abbreviated form. Appendix D provides the entire story.

TABLE 1

ZOK
* Hard skeletons
* Larger than human beings
* Can move

MIB	TUZ	FLOT
* A type of Zok	* A type of Zok	* A type of Zok
* Orange backs	* Orange backs	* spiny-backed
* angular	* smooth-arced contours	* angular
* live in trees	* live in caves	* live in forests
* very aggressive	* friendly	* avoid people
* eat flesh	* eat vegetation	* eat flesh
* edible	* nonedible	* edible
Pif	Pram	Ruc
* A type of Mib	* A type of Tuz	* A type of Flot
* blue-bellied	* red-bellied	* striped sides
* square body	* round body	* black body
* moves in lazy swings	* move in skips	* run gracefully
Luk	Selk	Nar
* A type of Mib	* A type of Tuz	* A type of Flot
* Pink-bellied	* purple-bellied	* dottes sides
* rectangular body	* oval-shaped body	* transparent body
* moves in quick jumps	* jump from place to place	* waddle slowly

One-hundred-seven propositional statements were devised to test set-set relationships and set-property relationships. The set-set statements were of the type "A Pif is a Zok." Set-property statements were of the type "A Mib is edible." Sixty-eight of the propositional statements were true and thirty-nine of the propositional statements were false. The propositional statements were constructed following the procedures of Collins and Quillian (1969).

The 107 propositional statements were divided into 17 experimental conditions. Eleven conditions covered true set-set and set-property relationships. Six conditions covered false set-set and set-property conditions. This difference in number of categories is inherent in the design as it is impossible to write false propositional statements about the most inclusive set in the

hierarchy.

Both the network model and the feature-comparison model made predictions (often contradictory) about the propositional statements as we had written them. Smith et. al. (1974) used the same conditions by which we set-up our category schema with one exception -- they did not precisely specify the number of characteristic and defining features shared by different items in the sets. In the present study, in which we created the features rather than relying on subject's pre-existing memories, the number of like and unlike features were identified a priori. From this scale of similarity (e.g. 1/5 of features shared, 2/5 of features shared, etc.), that degree of similarity necessary to force the execution of stage II processing (as explained by the feature-comparison model) could hopefully be identified.

Apparatus: The propositional statements were typed on 4" x 6" plain-white cards and presented using a tachistoscope. The experimenter pushed a button which simultaneously illuminated the card for the subject and started a digital clock accurate to 1/10,000 of a second. Once the subject had decided whether the propositional statement was true or false he pushed a response button which indicated his choice and simultaneously stopped the clock. Reaction time (RT) calculations are extremely accurate when recorded using a tachistoscope in this manner. For this reason, tachistoscopes are often preferred to Cathoderay tube (CRT) displays in this type of experimental design (Lindsay & Norman, p. 310).

Procedures: The subjects were instructed to read the story about the animal kingdom of the alien planet and to be very familiar with the materials for a memory test. Subjects were given five days to internalize the stimulus information. The experimenters did not provide the subjects with any specific memorization strategy. Subjects were allowed to memorize the information in any way they desired.

All subjects were required to meet a criterion level of knowledgeableness about the information given in the story. Subjects were asked to respond to

verbally-presented propositional statements similar to those used in the 107 test sentences. All subjects demonstrated the knowledgeableness criterion within the same period of time (approximately ten minutes). After meeting the criterion, subjects rested five minutes before responding to the tachistoscope presentations of the statements. Immediately prior to the times test, subjects were given a ten statement presentation warmup to familiarize them with the tachistoscope and their response buttons.

Presenting the propositional statements required approximately fifty minutes. This included a ten minute rest pause half-way through the test. The order of statement presentation was derived from a random numbers table. This order was reversed for one-half of the subjects to cancel possible priming effects. The procedures presented in this section were derived from those used by Smith, Shoben and Rips (1974) and by Collins and Quillian (1969).

Results

Table 2 presents obtained mean reaction times (RTs) for each of the seventeen categories (see Table 2). The obtained RTs were compared between categories following predictions from both the Network model and the Feature Comparison model. The t-test was used to compare obtained RTs across categories. The $p=.05$ significance level was used for all statistical analysis.

Network Model Predictions

The Network model makes clear predictions for true set-set and true set-property relationships as a function of distance in the network hierarchy. As distance between the semantic nodes in the hierarchy increases, RT is expected to increase. For example, the RT for S_0-S_1, true relationships should be faster than RT for S_0-S_2 true relationships. No difference between RTs is predicted between set-set or set-property relationships where the semantic nodes are equidistant in the hierarchy. The Network model predicts that false relationships will generate RTs that are longer and more variable than RTs for true comparisons.

Table 3 presents the directional predictions of the Network model between

TABLE 2

Category	RT	Category	RT
S_1-S_1 True	.1206	S_0-S_1 False	.3241
S_0-S_0 True	.1311	S_1-S_1 False	.3285
S_2-S_2 True	.1530	S_0-S_0 False	.3403
S_1-P_2 True	.2030	S_1-P_1 False	.3435
S_0-P_2 True	.2039	S_0-P_0 True	.3490
S_1-S_2 True	.2104	S_0-P_1 True	.3666
S_0-S_2 True	.2234	S_0-P_1 False	.3714
S_0-S_1 True	.2986	S_0-P_0 False	.4326
S_1-P_1 True	.3097		

S_2=Zok S_1=Mib, Tuz, or Flot S_0=Pif, Luk, Pram, Selk, Ruc, Nar

P_2= property stored at level S_2 P_1= property stored at level S_1

P_0= property stored at level S_0

true set-set categories (see Table 3).

It is important to notice that the first six predictions that support the Network model may be explained by pattern recognition (e.g. a Zok is a Zok) as well as by a hierarchical memory structure dependent on cognitive economy (storing properties at only one level in the hierarchy). Those tests we felt were <u>critical</u> tests of the Network model are: 1) RT for S_0-S_1 is less than RT for S_0-S_2, and 2) RT for S_1-S_2 is less than RT for S_0-S_2. In the first instance our data <u>contraindicated</u> this prediction. In the second instance the prediction was not supported at p=.05.

Table 4 presents the directional predictions of the Network model between true set-property categories (see Table 4).

TABLE 3

Category 1	RT	Prediction	RT	Category 2	Statistical Relationship
S_0-S_0 True	.1311	is less than	.2986	S_0-S_1 True	*
S_0-S_0 True	.1311	is less than	.2234	S_0-S_2 True	*
S_1-S_1 True	.1206	is less than	.2986	S_0-S_1 True	*
S_1-S_1 True	.1206	is less than	.2104	S_1-S_2 True	*
S_2-S_2 True	.1530	is less than	.2234	S_0-S_2 True	*
S_2-S_2 True	.1530	is less than	.2104	S_1-S_2 True	*
S_0-S_1 True	.2986	is less than	.2234	S_0-S_2 True	*
S_1-S_2 True	.2104	is less than	.2234	S_0-S_2 True	#
S_1-S_2 True	.2104	is less than	.2234	S_0-S_2 True	@

*= difference in Mean RTs significant at p= .05

#= difference in Mean RTs significant at p= .05 contrary to prediction

@= difference in Mean RTs not significant at p= .05

(see Appendix A for t-test computations)

As Table 4 shows, results supported predictions only eight times at p=.05. In three of the eight tests the predictions were contraindicated at p=.05. Four of the eight tests generated no support at p=.05.

Table 5 reports False categories compared with the corresponding true categories (see Table 5).

Although Network predictions were supported at p=.05 only one of the four times, in every comparison the Mean RTs for false categories was greater than the Mean RT of the corresponding True category.

Feature Comparison Model Predictions

The Feature Comparison model predicts increases in Mean RTs as a function of "sufficient similarity or dissimilarity between an item and its category."

TABLE 4

Category 1	RT	Prediction	RT	Category 2	Statistical Relationship
S_0-P_0 True	.3490	is less than	.3666	S_0-P_1 True	@
S_0-P_0 True	.3490	is less than	.2039	S_0-P_2 True	#
S_0-P_1 True	.3666	is less than	.2039	S_0-P_2 True	#
S_1-P_1 True	.3097	is less than	.2030	S_1-P_2 True	#
S_1-P_1 True	.3097	is less than	.3666	S_0-P_1 True	*
S_1-P_2 True	.2030	is less than	.2039	S_0-P_2 True	@
S_2-P_2 True	.1986	is less than	.2030	S_1-P_2 True	@
S_2-P_2 True	.1986	is less than	.2039	S_0-P_2 True	@

*= difference in Mean RTs significant at p= .05

#= difference in Mean RTs significant at p=.05 contrary to predictions

@= difference in Mean Rts not significant at p=.05.

(see Appendix B for t-test computations)

TABLE 5

Category	RT	Prediction	Category	RT	Statistical Relationship
S_0P_0 True	.3490	is less than	S_0P_0 False	.4326	*
S_0P_1 True	.3666	is less than	S_0P_1 False	.3714	@
S_1P_1 True	.3097	is less than	S_1P_1 False	.3435	@
S_0S_1 True	.2986	is less than	S_0S_1 False	.3241	@

*= difference in Mean RTs significant at p=.05

@= difference in Mean RTs not significant at p=.05

(see Appendix C for t-test computation)

Those items which share all the properties of its category are reflected in very fast RTs. Items which share no properties with its target category also generate fast RTs. Ambiguous instances (e.g. is a bat a bird?) should be reflected in relatively long RTs.

To test the Feature Comparison model we categorized the data as a function of properties shared between an item and its target category. Because of the construction of the stimulus item, only false relationships could be tested on this continuum of similarity. We feel this should be noted and considered a limitation of the results reported. Table 6 presents the data relevant to testing the feature comparison model (see Table 6).

TABLE 6

Variable (i/j) where i= shared properties and j= unshared properties	RT
Variable 1 (3/9)	.3414
Variable 2 (4/8)	.3118
Variable 3 (5/7)	.3214
Variable 4 (4/4)	.3285
Variable 5 (5/3)	.3182
Variable 6 (3/5)	.3693
Variable 7 (9/3)	.3297

In no comparisons did the difference in Mean RTs offer support for Feature Comparison predictions at p=.05.

Discussion

As outlined in the results section, our data supported neither theory in the most essential of the tests run. Thus, in the critical comparison of the two theories, neither can be said (from our data) to be more useful than the other.

A likely explanation for our results (i.e. contrary to predictions of both models) is that the stimulus material was very different from that used by

Collins and Quillian (1969) and Rips, et al. (1975). If this explanation is accurate, then semantic memory may be structured partly by the message received and partly by the communicative setting in which the message is transmitted. These structuring components are not part of either the Network model or the Feature comparison model.

Feature Comparison and Network models both postulate semantic memory as functioning below the level of conscious awareness. For much of the information that we hold in semantic memory, this assumption may well be valid. It is difficult to trace a conscious component of meaning assignation to "Please pass the salt."

However, all of our information and message exchanges are not so context-free. It is our position that people use conscious strategies for the processing and recall of certain messages. This contention is supported in the work of DeVilliers (1974) and Cofer (1977).

Returning to an interpretation of our results, our subject's semantic memory for the information may reflect conscious awareness in at least three areas: (1) The structure of the message (i.e. how the information is interconnected), (2) external processing cues or message attenuators (e.g. experimenter's instructions about how to process the message), and (3) subject's internal processing strategies that they consciously employed.

Evidence for the effect of external message structure comes in part from the subject's post-test comments on the experiment. Thirteen of the fourteen subjects reported that they drew tree-diagrams similar to the structure suggested by the Network model. The way the story was written (paragraphs individually devoted to the various families of creatures) may have helped the subject's organize the information in this way.

External processing cues were similar in some ways to those used in the past studies reviewed. Message receivers were instructed that they would be tested on a given body of information and told to do well on the test. This

request by the experimenter may have caused the subjects to employ a strategy that would insure a correct response. Spiro (1975) and Cofer (1977) argue that explicit instructions to process information for a memory experiment causes subjects to insolate the stimulus message from other memory structures. This isolation may affect semantic memory.

Several subjects reported that they consciously used recall strategies for the experiment. Most obvious was pattern recognition. In every instance where the subject term matched the predicate term (e.g. A Zok is a Zok) subjects immediately responded true as would be expected.

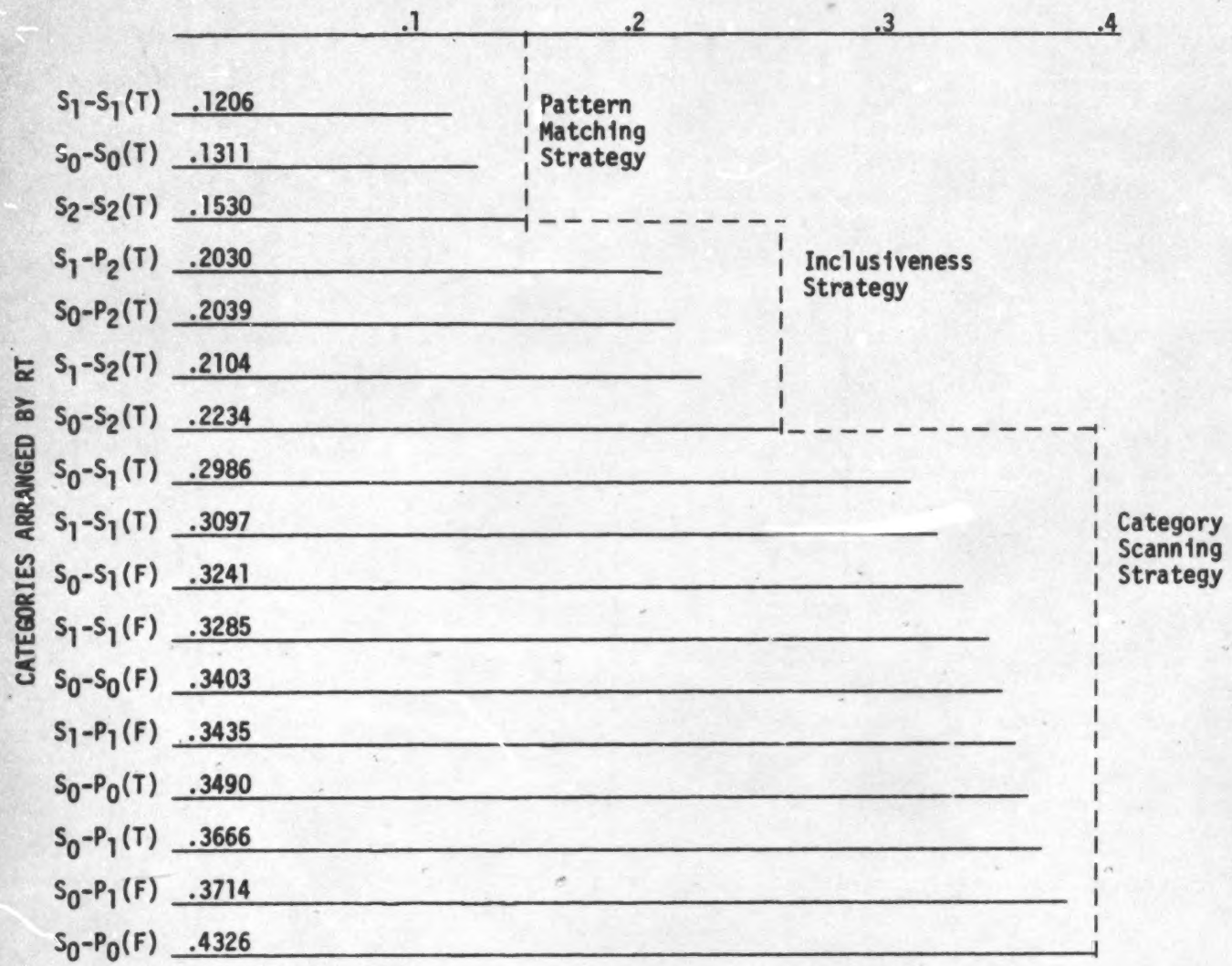
A second strategy employed was one of inclusiveness. Subjects reported that if a Zok could move and all creatures were Zoks then all creatures could move. An inclusiveness strategy effectively explains many of the results contrary to those of the Network model.

Finally, subjects may have used a category scanning strategy. As the number of properties that described a given test question increased, the RT also increased.

Given that this analysis is post hoc, the conclusions graphed below are tentative in nature (see Graph 1). Nonetheless, we feel that the data support quite well the contention that active, conscious strategies play a part in structuring semantic information in memory. As shown pattern matching is clearly the best strategy. Inclusiveness is also effective and explains well the results that contradicted the Network predictions. Category size also appears to impact the results slightly; in general as category size increases, RT increases.

Graph 1 (refer to Table 2 for notation)

MEAN RT in Seconds



In summary, semantic memory--the matrix to which incoming messages are compared for meaning--seems to be influenced by: (1) the form that the message takes, (2) cues external to the message as presented by the communicator (e.g. contradictory nonverbal cues), and (3) ways that people consciously order the messages they receive as a function of the context in which they are communicating (e.g. the meaning of "reliability" is different in a conversation between two methodologists as compared to the conversation between a paperboy and a subscriber). Further research is need to better determine the active, conscious role of the individual as he or she is engaged in the use of language.

APPENDIX A

t-tests for TABLE 3

$(S_0-S_0)--(S_0-S_1)$	t=5.03	df=13	p=.000
$(S_0-S_0)--(S_0-S_2)$	t=-4.07	df=13	p=.001
$(S_1-S_1)--(S_0-S_1)$	t=5.14	df=13	p=.000
$(S_1-S_1)--(S_1-S_2)$	t=-4.34	df=13	p=.001
$(S_2-S_2)--(S_1-S_2)$	t=2.83	df=13	p=.014
$(S_0-S_1)--(S_0-S_2)$	t=3.32	df=13	p=.008
$(S_1-S_2)--(S_0-S_2)$	t=2.83	df=13	p=.014
$(S_2-S_2)--(S_0-S_2)$	t=2.61	df=13	p=.021

APPENDIX B

t-tests for TABLE 4

$(S_0-P_0)--(S_0-P_2)$	t=7.15	df=13	p=.000
$(S_0-P_1)--(S_0-P_2)$	t=9.19	df=13	p=.000
$(S_1-P_1)--(S_1-P_2)$	t=4.49	df=13	p=.001
$(S_1-P_1)--(S_0-P_1)$	t=2.51	df=13	p=.026

APPENDIX C

t-tests for TABLE 5

$(S_0-P_0)--(S_0-P_0)$	t=5.65	DF=13	2-tail prob=.000

APPENDIX D

LAST DAYS ON CORINTHIAN

And as the cloud of rust-red dust engulfed the tiny spaceship cutting off further radio contact, Cruise Control in Dallas heard these closing words: "Mountains, yes; and rivers, the air seems breathable; but the light--everything is bathed in pale blue!"

"Well, we're alive," muttered the captain of the downed Agamemnon, "but the engine's nothing but stellar scrap." "Where's the biologist Bower," he thought. "Might as well begin classifying the life here--if there is any."

Two years later when the rescue ship finally arrived from earth they located the Agamemnon, perfectly preserved. But inside the ship three men didn't move, each one's lips lightly tinted blue. Beneath the pen of biologist Bower in simple, elegant script were the words: "It has ended. Know these creatures well; it could save your life." And turning the pages of the biologist's journal, the captain of the rescue ship read the following classification of the life forms found on the planet Corinthian:

"These creatures I will call them Zoks all have hard skeletons, are much bigger than human beings, and can move about their environment. Mibs are a kind of Zok that eat flesh. All Mibs have orange backs and appear very angular to the observer. They live in trees. If you happen to look up and see a blue-bellied, square creature moving in lazy swings through the trees beware for this is a Pif. Pifs are a very agressive category of Mib. Perhaps an even more dangerous type of Mib is the Luk. Luks have pink bellys, are rectangular in shape and can jump quickly through the trees. Both Pifs and Luks are very agressive. All Mibs are delicious food for human beings.

Tuzs live in caves. Tuzs have orange backs, are identifiable by their

smooth-arced contours and eat vegetation. There are contours and eat vegetation. There are two kinds of Tuzs--Prams and Selks. Prams are red-bellied, round, and move across the land lightly in skips and are very friendly. Selks are purple-bellied, oval-shaped and jump from place to place. They are also friendly but they are very shy for being a Tuz. None of the Tuzs, neither Prams or Selks, are edible by human beings.

Flots are the third type of Zok. They are spiny-backed, live in forests and are flesh-eaters. All Flots avoid people and are very angular in appearance. Rucs are one kind of Flot. Rucs have striped sides, black bodies and run gracefully across the ground. Rucs are edible by people and have a delicate flavor. Nars are the other kind of Flot. Nars have dotted sides, transparent bodies, and waddle slowly amongst the trees. While edible like all Flots, Nars are virtually tasteless."

The journal entry closed with: "My work is now completed; learn these creatures well. You'll be living with them until the end of your days. Look up into the pale blue light and remember the lovely red you saw looking down. You have entered a time warp and cannot return. Learn the Zoks, and the subcategories of Zoks for they are your only source of food; and of danger. Some can offer you friendship, others a battle for your life. Take this test to measure your likelihood of survival. Then go out into the strange, blue light of Corinthian--and good luck."

Space Biologist William A. Bower
Star Ship Agamemnon

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